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ABSTRACT

The aim of this study was to investigate the strategies leading to test item responses in 60 young (20-25 years) and 60 middle-aged (35-40 years) adults, whose highest level of education had been either secondary, technical or university. Subjects were individually administered a 12 item test similar to Raven's Progressive Matrices, and were required to describe in detail the thinking underlying each solution. Pass rates did not differ according to age or educational status, but this masked differences between the groups in strategy choice. Older and technically educated subjects were more likely to adopt non-analytic strategies, depending on item type. It was suggested that the age differences may be precursors of later decline in old age, and that technical education which in Australia is vocationally specific, may rely less on abstract cognitive skills. References and tables are appended. (Author/LMO)

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Strategies Underlying Psychometric Test Responses in Young and Middle-aged adults of varying educational background

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Abstract

Knowledge of the processes underlying the solution of psychometric test items can assist in explaining the effects of variables associated with group and individual differences in cognitive abilities. While stability in test performance is typical from early to middle adulthood, there may be qualitative differences in approaches to item solution. Studies of the effect of education often use length of education as an index, whereas type of education may also be a salient variable. The aim of this study was to investigate the strategies leading to test item responses in 60 young (20-25 years) and 60 middle-aged (35-40 years) adults, whose highest level of education had been either secondary, technical or university. Subjects were individually administered a 12 item test similar to Raven's Progressive Matrices, and were required to describe in detail the thinking underlying each solution. Pass rates did not differ according to age or educational status, but this masked differences between the groups in strategy choice. Older and technically educated subjects were more likely to adopt non-analytic strategies, depending on item type. It was suggested that the age differences may be precursors of later decline in old age, and that technical education which in Australia is vocationally specific, may rely less on abstract cognitive skills.

Intellectual functioning in adulthood and old age has received considerable attention in recent years. In discussing previous reviews of adult and life-span development research, Birren, Cunningham and Yamamoto (1983) state that this area of behaviour has received more attention than any other topic. Yet Birren et al. argue that the factors that account for age differences in intellectual abilities are poorly understood. This can be illustrated with reference to two issues that have been debated in the last decade: the nature and extent of cohort effects obtained from cross-sectional and cross-sequential comparisons, and the interpretation of age changes in psychometric test performance observed longitudinally.

Hultsch and Deutsch (1981) concluded that there is evidence for both cohort differences and age decline. Birren et al. (1983) concur with this but question whether the relative size of cohort and age effects in volunteer samples reflects accurately the extent of age and cultural changes in the general population. In this connection Horn and Donaldson (1976) claim there is positive bias in existing studies, such that greater intraindividual decline would be likely in "dropouts" from these studies, and in those choosing not to participate. Hence the implication of studies of select, volunteer groups is that cohort effects would tend to be overestimated relative to genuine age changes which would be underestimated. Horn and Donaldson further identify a difficulty with the explanation of cohort effects. They state that "it is commonly assumed that the older (on the average) have poorer formal education than the younger, and that this should result in cohort differences" (p.716). However, in apparent paradox, the performance of older adults shows least decline on tests of

crystallized intelligence which rely on educational attainment, and greatest decline on tests of fluid intelligence which are held to be less reliant on knowledge acquired through formal education. The resolution of such problems requires information that Birren et al. argue is still lacking in current research. While it may seem obvious that the different experiences of those born and brought up in different generations would have some bearing on cognitive functioning, what the relevant differences are and how and to what extent they exert their influence remain to be elucidated.

With respect to individual change, Birren et al. (1983) and Schaie (1982) assert that there is little evidence for decline in psychometric abilities until the age of about 60. This generalization requires two qualifications. First, if it is acknowledged that intelligence is not unitary, not all abilities may show decline, and they may not decline at the same rate (Horn & Donaldson, 1976). Second, as Honzik (1984) emphasizes, there is considerable individual variability in the onset and rate of decline. This has been attributed to initial level of ability (Horn & Donaldson) and experiential factors, such as education, occupation, or more generally, the degree of stimulation offered in the environment (Honzik, 1984; Horn & Donaldson, 1976).

Each of these issues raises questions that have yet to be fully resolved in the literature. While Horn (1978) offers evidence that fluid intelligence is more susceptible to aging than crystallized intelligence, it has also been claimed that there is a process of "neointegration" or "dedifferentiation"

whereby abilities become more related or interdependent with increasing age (Baltes, Cornelius, Spiro, Nesselroade & Willis, 1980). This has been inferred from findings of increased factor covariance, and higher correlations between measures of fluid and crystallized intelligence, in older adults (Baltes et al., 1983). Looft (1972) denies that this process is a simple reversal of the differentiation taking place earlier in childhood, arguing that a lifetime of intervening experiences makes it impossible for the aging adult to revert to cognitive structures identical to those observed in children. Careful and detailed study of the changes in cognitive functioning occurring in adult development are needed to supplement the psychometric data supporting the notion of neointegration.

The individual variability observed in age decline also requires more clearly articulated linkages with the experiential variables claimed to underlie differences in rate and onset. If, as has been argued, the more highly educated person maintains a higher level of functioning for a longer period and declines more slowly (Vernon, 1979), how does formal education, which may have been completed decades earlier, affect the cognitive processes involved in successful performance on psychometric tests? Kesler, Denney and Whitely (1976) suggest that previous education affects lifelong occupational and leisure activities which will have direct relationships with intellectual functioning. This could provide for the better educated more opportunities for rehearsal of skills, the implication being that those abilities drawn on more frequently have a greater likelihood of being maintained (Denney & Denney, 1982). Another, but not

competing, possibility is that the better educated adopt different modes of processing, and use available cognitive structures in a different way (White & Ferstenberg, 1978). Education has been found to be a significant predictor of adult problem solving ability and performance on Piagetian tasks (Chap & Sinnott, 1977-78; Denney & Denney, 1982; Kesler, Denney & Whitely, 1976; Neimark, 1979; Sinnott, 1975; White & Ferstenberg, 1978). However the precise way in which education and other life experiences influence intellectual abilities and their decline is still open to question. Carroll & Maxwell (1979) are critical of the claims made in this regard, and assert that psychologists are still unable to make "clear and well-supported statements about the ecological relevance of these abilities or about how they might be susceptible to modification through different social and educational manoeuvres" (p.633).

The foregoing discussion suggests that new approaches are required in order to provide the deeper understanding called for by Birren et al. (1983) and Carroll and Maxwell (1979). It is contended that psychometric test data are a superficial source of information about age differences in ability. If the old do in fact perform more poorly, then our real concern should be with the nature of the cognitive processes underlying test performance and the way in which they differ from the processes characteristic of a younger age, a different cohort, or an individual of the same age with different life experiences. This is not a new notion; similar sentiments have been expressed on numerous occasions in the literature (Carroll, 1976; Garcia, 1981; Peterson, Swing, Braverman & Buss, 1982; Whitely, 1977) and a plea has been made for more effective integration of psychometric findings and those from experimental cognitive

psychology (Carroll & Maxwell, 1979; Glaser, 1981). There is a variety of evidence from the latter discipline that is of clear relevance to the interpretation of psychometric data. One significant finding is that successful solution of reasoning tasks can be achieved through the use of strategies other than the formal algorithm (Hunt, 1974; Goldman, Pellegrino, Parseghian & Sallis, 1982). Thus, while one may agree with Horn & Donaldson that "correlate-educing, concept-forming, relation-perceiving qualities ... are ... basic to intelligence" (p.709, 1976), it is possible for example to achieve scores in the normal adult range on Raven's Progressive Matrices without drawing on these qualities (Hunt, 1974). One implication of this for aging is that stability in test scores from early to middle adulthood may mask more subtle changes in cognitive processing that are precursors of later decline in performance. A second finding from experimental studies concerns differences in the problem-solving strategies used by younger and older adults. A common theme appears to emerge from this work: the old tend to adopt strategies that are less demanding or effortful, as well as being less efficient than those used by the young (Cohen & Faulkner, 1983; Denney & Denney, 1982; Hartley & Anderson, 1983; Hess & Higgins, 1983; Zacks, 1982). It is seen as important to determine whether the differences lie in the predication of the problem or in the execution of the strategy. The suggestion is made that the old differ in problem representation and hence strategy selection, rather than being unable to execute more efficient strategies (Cohen & Faulkner, 1983; Hartley & Anderson, 1983; Zacks, 1982). This kind of

information is clearly of relevance to understanding the functional significance of age differences in psychometric abilities. A drawback of the problem-solving literature is the proliferation of different tasks employed; a more direct approach to relating experimental and psychometric findings would involve studying the strategies used in solving psychometric test items.

It should be noted that the problem-solving studies cited above were all cross-sectional, and only one addressed the question of whether the differences found were age or cohort effects (Denney & Denney, 1982). Denney and Denney argued that as age and education were both significant predictors of problem-solving ability, this was evidence for both cohort and age differences. As in most studies employing education as a variable, it was operationalized as number of years or amount of education. To return to what was identified earlier as a key issue in aging research: we need to refine our conceptualization of education and other experiential variables if they are to have explanatory power for age differences. For example, type of education is no less important than amount of education. Even among the highly educated, there is evidence that cognitive task performance is related to type of college course undertaken and professional specialization (eg Commons, Miller & Kuhn, 1982; White & Ferstenberg, 1978). People proceeding from secondary school to wholly vocationally geared educational courses might be expected to function cognitively in a different way from those who pursue more "academic" courses in a university. Certainly, more attention needs to be given to qualitative differences in educational background when discussing cohort effects; even if older and younger adults were

matched on years of education, it is still possible that they vary in the particular kinds of educational experiences undergone.

The aim of the present study was to move in the directions advocated above by investigating the problem-solving strategies underlying the solution of psychometric test items in young and middle-aged adults whose highest level of education had been secondary, technical or university. While it would not be expected that the younger and older group would differ in average test performance, it is possible that they would vary in their use of strategies. If, as speculated earlier, changes in process precede performance decline in later years, one might expect less use of formal algorithms and efficient strategies in the older group. It would be predicted that the more formally educated university group would perform better than the secondary and technically educated groups. If more academic courses foster the maintenance of formal reasoning skills, one would expect to find greater use of formal algorithms and efficient strategies in the university educated group.

Method

Subjects A total of 120 subjects was tested, 60 aged 20-25 years and 60 aged 35-40 years. In each age group there were 20 subjects whose education had not proceeded beyond secondary level, but who had been educated to at least Year 10 standard; 20 subjects who had experienced at least two years of vocational training at a tertiary institution other than a university; and 20 subjects who had undertaken at least two years of a university degree course. These educational backgrounds were termed "secondary", "technical", and "university", respectively. Within each age x education group there were equal numbers (10) of males and females. Because of difficulties in recruiting subjects, recency of education, type

of course studied, and occupation were not controlled for. Subjects were sampled from as wide a variety of occupational and educational courses as possible.

Apparatus The test used was similar in format to Raven's Progressive Matrices, except that each item consisted only of the item stem (that is, the matrix) and contained no response alternatives. The test comprised three sets of four items. Within each set the matrices were structurally equivalent but varied in content: the logical form of the matrix was expressed in number, letter, pictorial and figural form. The three item sets differed in structure, and were ranked in order of complexity according to the mathematical relations by which the matrix was structured (see Thorburn, 1977). The length of the test was limited to twelve items, as a previous study had shown that it would take subjects about an hour to give detailed descriptions of the strategies employed in each item (Macrae, 1983).

Procedure Each subject was individually administered the test in his/her own home by one of four undergraduate Psychology students assisting in the experiment. The subject was given a booklet of the test items, a sheet printed with standard instructions, and a pile of loose sheets of blank paper. The test items were presented in random orders. The experimenter read the instructions aloud while the subject followed the instruction sheet. Subjects were asked to write down in as much detail as possible all stages of their thinking from first looking at an item until a solution had been generated. Subjects were free to express themselves verbally, or in pictures, diagrams or symbols. It was felt that the test was administered in such a way as to meet the criteria set up by Ericsson and Simon (1980)

for the acceptability of introspective reports as data reflecting the mental problem-solving process. After completion of the test, the response sheets were collated and stapled and identified with a random number to enable subsequent classification of strategies to be done by a different assistant blind to the age and education of the subject. The classification of strategies for each subject was cross-checked by at least one other assistant, with unclear cases being resolved at regular sessions where the author and the four assistants discussed general principles of classification as well as individual examples.

Results

A general summary of the results is given at the end of this section. Preceding that are the findings in relation to pass rates, strategies underlying correct responses, and strategies underlying incorrect responses. As no interactions between age and education were found, only summary data relating to the main effects of age and education are reported for the sake of br evity.

Pass rates

Table 1 below shows for each item type the pass rate in each age and education group, averaged across the four items of each type. The item types are ranked such that 1 represents the simplest type of item and 3 the most complex type of item.

TABLE 1 ABOUT HERE

For each item, the number of correct responses was cross-classified according to age and educational group and

the results analyzed by x^2. There was no significant difference in performance between the younger and older subjects, and while there was a trend for higher levels of education to be associated with improved performance, this was not significant at the 0.05 level.

Strategies used in correct responding

Correct responses were classified according to whether the solution had been obtained by use of the algorithm or "ideal" strategy, or by an alternative strategy which nevertheless allowed production of the correct answer. In problems of this type, it is the intention of the test constructor that the subject educe the relation holding between the cells in the first row of the matrix, confirm that it holds in the second row, and on that basis educe the missing part of the matrix in the third row; this procedure should then be repeated for the columns of the matrix (Raven, 1940; Spearman, 1927; Thorburn, 1977). It is this strategy that was termed the algorithm. However it was found that some subjects adopted alternative approaches in obtaining the correct answer. One was a partial strategy where subjects failed to use all the information available in the problem; for example, using only rows or columns to educe and verify relations, but not both. Another was a "holist" strategy which occurred in two variants: the subject treated each row or column as a whole unit of information, or treated the whole matrix as a single unit of information, rather than each cell of the matrix as a separate unit of information. Owing to low frequencies of each individual alternative within items and age x education groups, only frequency of use of the

algorithm was statistically analyzed. Table 2 below shows for each item type the percentage of each age and education group using the algorithm to obtain the correct answer, averaged across the four items of each type. Within each group, the remaining percentage had therefore used alternative strategies to arrive at the correct response.

TABLE 2 ABOUT HERE

For each item, the number of subjects using the algorithm to produce the correct answer was classified according to age and education and the results analyzed by x^2. On the simplest type of item, there was significantly less use of the algorithm in older subjects compared to younger subjects, for all four items. There were no significant education effects. On item type 2 there were no significant effects of age or education. On item type 3, the most complex items, no significant effects of age were found, but on two of the four items education had a significant effect. The trend was for fewer technically educated students to use the algorithm compared to secondary and university educated subjects. Although the same trend was observed in the other two Type 3 items, the results were not statistically significant.

Strategies used in incorrect responding

Incorrect responses were classified according to the type of strategy used in generating responses. It became necessary to set up a category of "idiosyncratic" responses, so called because the individual's strategy was peculiar to him/herself

and resembled that of no other individual. For example, on a pictorial item one response was "I like dogs and cats best, therefore there should be a dog and a cat but no other animals". It had been anticipated that, as in a previous study with younger subjects (Macrae, 1983), incorrect strategies would be systematic and occur in types common to many individuals. However the different classes of such strategies occurred too infrequently in the present study to permit statistical analysis. The simplest type of item also resulted in too few errors to be statistically analyzed. Hence Table 3 below presents only the percentage of subjects making errors whose strategies were idiosyncratic, for each age and education group, and averaged across the four items, for item types 2 and 3.

TABLE 3 ABOUT HERE

For each item, the number of idiosyncratic responses was cross-classified by age and education and analyzed by x^2. On item type 2 the technical group gave significantly more idiosyncratic strategies than the other two educational groups. There was no effect of education. On item type 3 the older group responded idiosyncratically significantly more often than the younger. The apparent trend for higher levels of idiosyncratic responding in the technical group was not significant.

Summary of results

In general, there was no evidence of differences in performance according to the age or educational status of the subjects, as indexed by number of items solved correctly.

However similarities in test scores masked systematic variability in solution strategies.

On the simplest type of item, the older subjects were far more likely to adopt alternatives to the formal algorithm in correctly solving these items. There were too few data to analyze incorrect strategies.

On item type 2, the items of middling complexity, all groups were equally likely to use the algorithm, but about a quarter of all subjects adopted alternative approaches to correct solution. When these items were solved incorrectly, approximately twice as much idiosyncratic responding was found in the technically educated group compared to the secondary and university groups.

On the most complex items, the incidence of alternatives to the algorithm was higher in the technical group, for correct responses. Use of alternatives was quite high: about half of the secondary and university educated subjects, and three quarters of the technical group adopted such strategies. Idiosyncratic responding occurred most frequently in the older subjects, with just over half of their incorrect responses being of this type compared to a quarter in the younger group.

In summary, age differences and educational differences were not uniform, but varied as a function of item type. Age differences in strategies underlying correct solution appeared only on the simplest type of item; for strategies underlying incorrect responses, they emerged only on the most complex type of item. Educational differences in strategies leading to correct solution were present only on the most complex items;

they showed up in strategies underlying error responses only on items of medium complexity.

Discussion

It is of interest to note that no interactions between age and education were obtained in the present study. In view of the suggestion that less age change would be likely in the better educated (Horn & Donaldson, 1976), interactions might have been expected. There are two possible reasons they did not emerge. One is that the impact of education on age change is more important in later adulthood; the oldest subjects in this study were 40 years old. The other is simply that the often low frequencies of occurrence of responses within age x education groups resulted in a loss of power for detecting interactions. The difficulties in recruiting more than 20 subjects within each group made this inevitable. In any case, the discussion that follows will focus only on the main effects of age and education.

As was expected, the older and younger subjects did not differ quantitatively in solution of the matrices. The differences between the two age groups in problem predication are fruitful in view of the criticism of Cohen and Faulkner that "most studies of age effects have not differentiated between age differences that are due to changes in strategy selection and those that are due to changes in the efficiency of strategy operation" (p.447, 1983). The qualitative differences observed here amply support the contention that older and younger adults approach cognitive tasks differently (Cohen & Faulkner, 1983; Hartley & Anderson, 1983; Zacks, 1982). In tasks requiring the educ tion of relations and correlates, of which matrix items are an instance, two forms of predication of the problem can be

identified. First, the relation educed may not be that intended by the task constructor, but nevertheless may permit correct solution of the task (Goldman et al., 1982). Second, the problem may also be solved correctly without the individual's realizing the nature of the task: Raven himself noted that "testees frequently perceive a matrix of relations as a whole without clearly perceiving that explicit relations exist between the individual figures" (p.14, 1940). This is akin to the " holist" strategy referred to earlier, and Hunt (1974) makes a similar distinction between this type of approach and the algorithm, referring to "Gestalt" as opposed to "analytic" strategies in matrix items. When relation/correlate-educing tasks are solved incorrectly, two broad approaches are again possible: an erroneous relation may be educed, or the subject may fail to recognize that the task calls for the eduction of relations, for example completing the matrix to create an esthetically pleasing pattern. It has been argued that older adults are less inclined to appeal to analytic relations (for example, class membership) and are more inclined to relate items of information associatively or functionally (Denney & Denney, 1982). Sinnott and Guttman (1978) relate this to the functioning of the old in daily life. They obtained data to support their assertion that an understanding of classes and relations is necessary in "everyday" problem solving.

Because age-related variations in strategy selection were observed despite no age differences in successful solution, this is regarded as support for the earlier suggestion that some underlying cognitive changes may begin taking place in adulthood before the onset of psychometric test score decline.

It is important to point out however that the age differences obtained were not uniform across the test domain, but depended on the type of item. Carroll and Maxwell have stressed the need to know more about the individual's "characteristic solution strategies as they interact with problem type" (p.617, 1979). The greater levels of idiosyncratic responding in the older group on the most complex items can perhaps be understood in terms of the argument of Goldman et al. (1982) that tentative relational understanding is displaced by weaker associative strategies when the demands of the task are beyond the capacity of the individual. One must also assume that complex tasks become more difficult with increasing age. The remarkable preponderance of alternatives to the algorithm in the older group on the simplest of the three types of item may reflect a tendency towards Gestalt approaches to problem solution as one ages, and it may be that simpler forms of item lend themselves more readily to these holistic strategies. Whatever the true explanation, the interaction between age and problem type in their effect on cognitive processes deserves further study.

A point of caution is in order: there may be unknown cohort differences in operation. Though education was to a certain extent controlled for, its effect as a cohort variable was not eliminated but only reduced. But the effect of education is of some interest as it was the technically educated group that made most use of non-analytic and diversified strategies, again according to item type. If length of education were a potent variable, it would be expected that the secondary educated subjects would differ most, as the technical and

university group had received at least two years of post-secondary education. The present findings support the notion raised earlier that type of education is at least as crucial. The specialized vocational training of the technically educated may inhibit the generalization of cognitive abilities and abstract thinking of the type required in matrix problems. It is less easy to explain why their greatest use of alternatives to the algorithm occurred in the most complex items, whereas in the older group this had occurred with the simplest items. Similarly it is difficult to conceive why the technical group differed most in idiosyncratic responding on the middle set of items, while the older group differed most on the most complex items. All that can be concluded is that age and education may not exert comparable effects on cognitive functioning. This suggestion nevertheless warrants further investigation to explore the possibility that quantitatively similar effects of age and education conceal qualitatively distinct processes. It is plausible that the changes in the types of problems one encounters as one ages are not the same as the differences in the types of problems faced by those with different educational and occupational backgrounds.

In conclusion, it is felt that further study of problem-solving strategies as they pertain to the solution of psychometric test items is a fruitful avenue of research. With more detailed knowledge of a range of demographic and experiential variables and greater numbers of subjects, it is an approach that may help to illuminate the underlying functional significance of age decline in intellectual abilities. But to finish on a more

positive note: despite the pessimism of Birren et al. (1983) regarding our present understanding of aging, they call attention to the value of recent research into plasticity in adult development. Intervention programs aiming to halt decline and enhance the abilities of the elderly (Baltes & Schaie, 1976) hold out hope that with a more complete theoretical account of the aging process, real control can be achieved over the life experiences that promote good thinking skills.

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TABLE 1

Average pass rate in each item type

according to age and education

Item Type	Age		Education		
	Young	Old	Sec.	Tech.	Uni.
1	.86	.89	.82	.86	.96
2	.51	.49	.39	.51	.60
3	.53	.55	.40	.51	.73

TABLE 2

Percentage use of algorithm in each

item type according to age and education

Item Type	Age		Education		
	Young	Old	Sec.	Tech.	Uni.
1	76.1	16.8	43.4	48.3	47.8
2	58.5	68.7	76.8	50.8	63.2
3	40.2	46.0	46.0	32.0	51.2

TABLE 3

Percentage idiosyncratic responding in each item type according to age and education

Item Type	Age		Education		
	Young	Old	Sec.	Tech.	Uni
2	40.1	34.7	26.8	58.1	27.3
3	25.2	55.7	31.6	50.1	39.6